

ESF Exploratory Workshop on
**IMAGE-GUIDED LAPAROSCOPIC
THERAPIES**

Cáceres (Spain), 15-17 June 2011

Convened by:
Francisco M. Sánchez Margallo
and
Enrique J. Gómez Aguilera

SCIENTIFIC REPORT

Co-sponsor



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1. Executive summary

The **ESF EMRC Exploratory workshop on Image-guided Laparoscopic Therapies** (with reference code EW10-011) took place from 15th to 17th June 2011 at the Jesús Usón Minimally Invasive Surgery Centre (JUMISC) in Cáceres (Spain). It was convened by Dr. Francisco M. Sánchez-Margallo, Scientific Director of JUMISC, and co-convened by Enrique J- Gómez-Aguilera, full professor at Technical University of Madrid.

In all, 24 of the 25 invited participants attended from nine ESF member countries (Austria, Belgium, France, Germany, Norway, Portugal, Spain, The Netherlands and United Kingdom), representing a range of disciplines involved in soft-tissue surgical procedures, cognitive ergonomics, endoscopic video analysis, intraoperative imaging acquisition, image registration, real-time tracking, deformation of the virtual models of organs, surgical training and surgical assessment, among others.

Main Objective

The main objective of this workshop has been to bring together European groups which are involved in the development of innovative therapeutic approaches and interventions in minimally invasive surgery (MIS). In this ambitious development, different roles are involved: surgeons, experts in surgical training, computer scientists, mechanical engineers, electronic engineers, ergonomists and biomedical engineers among others. This workshop on Image-guided laparoscopic therapy (IGT) brought together 24 European leaders in the field of IGT who were invited on the basis of their scientific excellence, potential contribution and reflecting a European dimension.

Conclusions

After all talks and discussions, it was concluded that the final aim of all technological developments must be always to improve surgery and the quality and safety of treatments and interventions for patients.

The most important future research topics on image-guided laparoscopic therapies have been outlined:

- * Surgical Process Modelling
- * Preoperative data and imaging (image processing, 3D models)
- * Intraoperative data and imaging
- * Registration (non rigid methods, etc)
- * Tracking technologies and methods
- * Biomechanical models (deformation of organs in real time)
- * Visualization
- * Surgical training
- * Assessment of surgical skills
- * Validation and assessment of surgical devices for training

General Logistics

16 participants arrived in the afternoon 15th June 2011 to Barajas airport in Madrid and were welcomed by two members of the organizing institution. Transfer from the airport to Cáceres was assured with a private bus service which also included the journey back to the airport

after the workshop. Two other participants arrived later at night also to Barajas airport and a private car drove them to JUMISC facilities due to unavailable public transport. Three participants arrived to JUMISC facilities on their own car in the afternoon 15th June and two more arrived in the morning 16th June with a rent car due to non available direct public transport from Coimbra to Cáceres. Participants went home on 16th June, except two of them who stayed one night in Madrid due to there were no planes in the evening. All plane tickets were booked for all foreign participants via a travel operator which JUMISC usually works with.

Lectures were held in Room A (54 seats and 90 m²) which is equipped with conference table with two monitors, wireless microphones, dual projection video and data, individual connection to the Internet, lectern with two monitors, voting system, simultaneous translation equipment, four TV screens of 40". Wireless Internet access was also available in the conference venue during the entire workshop.

13 participants stayed at the residence in JUMISC and nine stayed at Albarragena hotel, placed in the city centre. Since no other public transport is available from Cáceres to JUMISC, taxis were necessary for those participants staying at Albarragena Hotel. Displacement for participants staying at the residence in JUMISC for dinner on 16th June was covered with the private bus hired for the transfer between Barajas airport and Cáceres.

Dinner on 15th June, coffee breaks on 16th June and lunch on 16th June were served in a dinning room at the residence. Dinner on 16th June was at Parador de Turismo de Cáceres in the old town. Finally, coffee break on 17th July was served in the hall of JUMISC.

Taking advantage of the beauty of the old town in Cáceres, a guided visit was appointed with the Cáceres' tourism department. A professional guide explained the history and legends of the old city and some important monuments were visited. In all, the guided tour lasted two hours.

Costs of participants are covered by the ESF budget except for Mr. John Hyde (Perception, Sensors and Instrumentation, Doncaster, UK) whose costs are assumed by the Spanish Ministry of Science and Innovation if the submitted proposal is accepted or by the JUMISC if not.

Participants and atmosphere

After the communication of the award by the ESF on 25th November 2010, an invitation letter together with an online poll was sent to all participants included in the proposal in order to define the most suitable dates for most of them. Due to busy agendas on the selected dates, eight participants could not attend the workshop and were replaced by colleagues of their own institution. Three proposed speakers could not attend of whom two were replaced afterwards by other speakers.

Besides invited participants, one ESF rapporteur (Enrique Gómez Barrera - Hospital Fundación Jiménez Díaz / Universidad Autónoma de Madrid, Madrid, ES) participated in the workshop. An overview about the European Science Foundation was delivered before starting the first session.

Atmosphere was very cordial from the first meeting point at Barajas airport and during the transfer to Cáceres. Some participants knew each other in advance what made easier to

obtain a comfortable and confident environment. This situation made the workshop a profitable and nice experience for all participants. They were all very motivated and there was a general strong sense of collaboration and excitement. Therefore, discussions were not only during the scheduled times but also during coffee breaks, lunch and dinners in different small groups.

Last-minute Changes

Due to medical reasons Dr. Fernando Bello (Imperial College London) cancelled his participation the afternoon before the starting day. Therefore, his place was left vacant. The cancellation costs for his ticket are supported from the workshop budget.

Due to unforeseen delays, welcome at JUMISC and dinner at Parrilla de Galarza on 15th June had to be cancelled and dinner was served as previously mentioned in the dining room at JUMISC facilities.

2. Scientific content of the event

**For detailed information about the talks, please check the appendix where abstracts are included.*

16 June 2011

The day started with a short welcome to participants by the convenor of the workshop, **Dr. Francisco M. Sánchez-Margallo**, and co-convenor, **Prof. Enrique J. Gómez-Aguilera**. Afterwards, a presentation of the ESF was made by its rapporteur, **Dr. Enrique Gómez Barrena**. He exposed the objectives and scientific domains of the ESF, its budget and the different ESF activities.

Session 1: "Introduction and MIS needs"

Chairmen: Dr. Francisco M. Sánchez-Margallo and Prof. Enrique J. Gómez-Aguilera.

Dr. Francisco M. Sánchez-Margallo gave the first talk entitled "New approaches of laparoscopic techniques". He provided a clinical background on minimally invasive surgery and depicted the challenges regarding surgical training with special emphasis on the training model and devices which has been developed and are currently used at JUMISC. He ended his presentation with an exposition of research and clinical challenges associated with surgical training, assessment and navigation systems: MIS integration and combined systems to be used in the Operating Room (OR). Then, **Dr. Thomas Langø** took the word and gave the second talk of the session "The importance of intraoperative imaging and navigation technologies in MIS". He presented the "Future OR" at Saint Olavs Hospital in Trondheim which has a navigation system for laparoscopy. He explained the different reasons why a navigation system is necessary in this type of procedures and which information (mainly TC, MRI and ultrasound) and methodology they use to accomplish a navigation-guided procedure. He concluded with results of different experiences with real procedures in laparoscopic clinical routine in the retroperitoneum based on preoperative CT images, in endovascular therapy based on intraoperative contrast-based CT (CBCT), and in neurosurgery based on intraoperative ultrasound as the main imaging modality. Last talk was given by **Prof. Enrique J. Gómez-Aguilera** and was entitled "Image-guided technologies for minimally invasive surgery". He exposed a technological background on image-guided

laparoscopic surgery with a state-of-art of the different technological components: preoperative images, intraoperative information, registration between them, tracking of tools and organs, biomechanical virtual models and visualization of all the gathered information. The role of medical images and surgical video in the development of these new navigation systems was stressed. He finished his presentation with research challenges on image-guided surgery.

After these talks, discussion of session 1 was introduced by **Prof. Enrique J. Gómez-Aguilera** who talked about the aim of putting together the different research areas and identify topics to create a research agenda and then possibility of showing the trends and challenges that will be concluded in the workshop to the European Union so they could be included in a green paper and in the next Framework Program, (recently announced its name: Horizon 2020) that is currently under construction.

The following topics were the main ones exposed during the discussion:

Dr. Tomas Langø exposed that the navigation system based on preoperative images is now mainly used in procedures in the retroperitoneum because organs, like kidney or adrenal glands, do not move too much during interventions. Therefore, the next step is to focus on the liver and that is the point of using ultrasound for intraoperative imaging.

Dr. Pablo Lamata showed his concern about the fact that surgeons are still somehow reticent to use in some cases new technological systems so in his opinion there is a gap between technical prototypes and the final application of these systems in the OR. How could this gap be avoided?

Prof. Enrique J. Gómez-Aguilera mentioned the necessity of validating and assessing systems in all different approaches (ergonomics, reliability, accuracy...) before using them in the OR by interdisciplinary teams involving surgeons and technical staff.

Prof. Adinda Freudenthal commented that assessment has to be done from the very beginning, even before doing any research. Different technologies have to be integrated and it is not just to identify needs, to identify requirements and validation but also knowing how to work as a team within the OR and the workflow have to be considered as well. Since there are different aspects, it is difficult to assess the process in general. Considering all the targets (safety or workload, among others), a validation plan has to be done and the sooner the feedback is obtained, the better can be done with the process. Since this should be done from the beginning, it is at the final stage of implementation when the process is improved.

Dr. Enrique Gómez-Barrena exposed that in the area of total knee arthroplasty, it has been shown that the use of navigation systems offers no benefits in comparison to classic way, what leads to a significant drawback from the point of view of surgeons that technology has to overcome. He wondered whether this could be because in some cases, too much information is an inconvenient rather than an advantage for surgeons and whether this would be a problem of 1st generation of surgeons facing this type of navigation systems. Since technology is an evolving matter, at which point is it ready to be assessed?

Dr. Tomas Langø exposed that a great challenge is to define good measurement parameters in order to assess the clinical value of using navigation systems over the traditional way. In some specialties such as neurosurgery or trauma, it is not possible to carry out a randomized study. He put forward an example where in 15 out of 20 cases of colectomies changed significantly (more than 3 cm) the camera position due to navigation systems, but there is no way to know what would have happened if the camera would not have been moved so a real comparison cannot be done.

Prof. Pierre Jannin stated that validation is a very complex problem not only regarding patient outcome but also regarding other factors such as the decrement of stress or cognitive workflow. Therefore, to measure the impact of new technology in surgeons, medical staff and

surgeons, several validations must be done in a very structured way. In some cases, new technologies allow treating new patients (for example, smaller tumours) and this enhancement is not easy to measure since patients are not comparable.

Dr. Werner Korb mentioned that it is important to have in mind the other side of assessment which is the topic of training: technologies used for this purpose, theoretical concepts, basic and advance training, concept of training courses...

Dr. João Oliveira exposed that a future direction could be modelling in realtime what is happening in the surgery so it would be possible an online training system.

Dr. Francisco M. Sánchez-Margallo exposed his concern of there is still need of new technologies for training purposes that would help the transfer of knowledge acquired to the OR, since not all the training stages are supported by technology.

Dr. Enrique Gómez-Barrena apported that there are also logistic problems to be solved regarding to surgical training. Nowadays, an expert surgeon is responsible for surgeons under training and there are some aspects that can be taught with models and virtual reality but guiding surgeons under training in some situations requires them not only to visualize but also to feel, palpate or test and that cannot be addressed from outside the OR in an online format. Another issue to be discussed is how to qualify surgeons since in most specialties it is now being discussed how to homogenize assessment. Up to now, it is based on oral exams but there is still the need to find tools to assess surgical skills.

Session 2: "Image-guided interventions Part I"

Chairman: Dr. Stijn de Buck.

First talk of this session was given by **Dr. Stijn de Buck** and it was entitled "Intraoperative image acquisition". He started with a brief introduction of the endoscopy view and some developments in visible light acquisition. Then he explained the different alternative types to visible light imaging: X-ray imaging (also in 3D), (Laparoscopic) ultrasound imaging, iMRI and functional imaging. He concluded with possibilities of new developments such as cameras and pills and which issues must be still researched. Next speaker was **Dr. João Oliveira** with the talk "Considerations on 3D models for interactive surgery". He explained the different sources of information to build 3D models and afterwards some geometric considerations (surface normals and inconsistent surface normals); the need of geometry reduction for complex models and performance considerations were addressed. After, talk "3D image processing for image-guided therapies" was given by **Dr. Kawal Rhode**. He focused on cardiac catheter procedures with the aim of improving clinical outcome, reducing procedure time and reducing radiation dose. Then, he presented each step of the workflow for guidance: 3D image acquisition, segmentation, surface extraction, 2D-3D registration and visualization. He also addressed the problem of motion compensation and catheter tracking. Next speaker was **Dr. Lena Maier-Hein** with the talk "Intraoperative surface reconstruction for Augmented Reality (AR) guidance in computer-assisted laparoscopic interventions". She presented the idea of contactless real-time surface acquisition and explained pros and contras of the different ways of camera-based image acquisition: stereoscopy, structure from motion, structured light and time-of-flight (ToF). Then followed the talk "Intraoperative navigation: calibration and visualization" by **Dr. Stefanie Demirci**. She explained that in liver procedures, the 3D dimensional model of the patient that is used in liver resection interventions changes during the intervention itself and proposed a solution based on augmented reality with CT visible adhesive fiducials to provide an optimum overlay between the patient and the 3D model. She also presented the Laparoscopic Virtual Mirror which provided information about depth perception by means of augmented reality based on a previous 3D model. Next speaker was **Dr. Pablo Lamata** who presented "The

resection map as guidance during liver interventions". He presented the need of guiding the surgeon while accomplishing a liver resection procedure and commented different approaches and their limitations to solve the problem. He then presented the resection map and the concept of mental registration as the previous information that the surgeons have in their mind which is not in any way physically registered with the reality. So the aim is to build a 3D cartographical map of the liver to guide the surgeon during the procedure with the necessary landmarks to correctly identify the situation. Last talk before discussion was given by **Mr. Martijn Hemeryck** and was entitled "Model based liver segmentation for surgery planning". He made an overview of the strategies for model-based image segmentation based on examples: liver tumor segmentation using heuristics, liver segmentation using statistical models and liver vessel segmentation using physics-based models.

After these talks, discussion of the first part of session 2 was introduced by Dr. Stijn de Buck. The following topics were the main ones exposed during the discussion:

Dr. Lena Maier-Hein talked from her experience that reconstructed light is not disturbing for surgeons since infrared can be used and they are not visible for the human eye and more effort has to be put on this technology. In general, surgeons have to be able to choose if they want to show or not the images for navigation.

Dr. Stefanie Demirci commented that same appreciation that surgeons have to interact with the navigation system and it must provide an intelligent interface with possibility of showing the reconstructed model over the organs or not. For tumour resections, it is very interesting to show its position overlaid on the endoscopic image without having to turn off the endoscopic view and having a look on the preoperative model.

Prof. Pierre Jannin stated that surgical process modelling has to be relied on, since its aim is to give to surgeons the right information at the right time, in the right place and in the right way. This can be summarized as displaying the information that is relevant at one moment in the surgical procedures, which is the base of context-aware systems.

Dr. Matthias Baumhauer mentioned the communication of information to the user is done up to now without the proper techniques, since it always adds software or hardware. So definition and design of user interfaces is a huge research field.

Dr. Werner Korb stated that there is a need of training surgeons in the use of image-guided therapies and navigation systems, in hands-on courses where they can train real tasks that they will have to do.

Dr. Stefanie Demirci remarked that it is also important to teach surgeons about error (in segmentation, reconstruction...) from a visualization point of view: so user can be aware of errors in the system and discuss about errors and accuracy.

Session 2: "Image-guided interventions Part II"

Chairman: Prof. Pierre Jannin.

First talk of this session was given by **Ms. Patricia Sánchez-González** and it was entitled "Laparoscopic video analysis as an intraoperative source of information". She presented a methodology that allows a 3D tracking of the tools based on the automatic analysis of the image. Then she exposed a method to reconstruct a 3D surface of the visible patch of the liver. Next talk was given by **Dr. Matthias Baumhauer** and entitled "MITK platform for developing new navigation systems". He presented the free open-source software for medical image analysis and surgical navigation: architecture, ways of use and development process. He focused on the module for image guided therapies (hardware and processing layers), ending with an example of use. Next, **Dr. Judith Mühl** gave the talk "Real-time

detection and tracking for augmented reality environments". She made a presentation of what augmented reality is and which technologies are available showing an example of it. Then she presented some of the tracking devices and technologies and associated problems. Next talk was "Biomechanical models of soft tissues: real-time applications" by **Dr. Estefanía Peña**. She started with an overview of the problems to address when modelling soft-tissues and their relation with the issue of real-time simulations. She then presented two different models for soft tissues: classical hyperelasticity approach and Classical CMD approach and viscoelasticity. She finished the talk with some examples of models of different vessels to help surgeons to plan interventions. Next speaker was **Dr. Sandrine Voros** with the talk "Intraoperative tracking for laparoscopic surgery". She presented their approach for 3D tool tracking based on a geometrical model to describe the orientation of an instrument. This model is based on geodesic spheres and the condensation algorithm. She showed experimental results comparing different methods. Next talk, "3D reconstruction of the surgical scene using structured light" by **Prof. Marcos A. Rodrigues**, started with an introduction of the basis of the technique: stripe indexing and generation of 3D data. Then he presented different methods for hole filling and smoothing in 3D post-processing. He finished the talk with an example of liver registration that put forward the need of external markers for this objective. **Mr. John Hyde** was the following speaker with the talk "The role of industry in the progress of image-guided procedures". He exposed the importance of a good signal-to-noise ratio to obtain accurate measurements in image processing. Then he explained the requirements (resolution, depth of field, wave length or image acquisition speed, among others) and the considerations (motion, defect analysis, among others) to obtain an industrial application. He finished his talk with two examples of applications: one based on structured light projection in the near infrared for 3D modelling and another of high intensity pulsed illumination. Last talk of the session was given by **Prof. Pierre Jannin** and was entitled "Surgical process modelling (SPM)". He presented the importance of assisting surgery with models of the workdomain (patient, surgeon, surgical procedure, staff, tools...). Focusing on the surgical procedure, there is much implicit information when the surgeon performs the intervention that surgical process models try to formally describe. He presented a global methodology for surgical process modelling, explaining in detail each one of its steps: definition of the workdomain, structure for description, acquisition, displaying and reporting, analysis and computation of generic SPMs.

After these talks, discussion of the second part of session 2 was introduced by Prof. Pierre Jannin. The following topics were the main ones exposed during the discussion:

Dr. Sandrine Voros raised the questions that some technical issues regarding to calibration have to be solved in order to include these visual tracking techniques in the OR and meet its specific requirements. The calibration method has to be as less disturbing for the surgeon as possible to obtain proper navigation systems which really offer benefits.

Prof. Pierre Jannin stated that intraoperative imaging should also be adapted to a surgical process model in order to fit all the information in a proper and correct way. Patient data must be another input of the surgical process models. There are still some uncertainty on which is the best way of determining a surgical process model: should it take as basis the mean of procedures of a surgeon of a hospital department or of a region or of a country or internationally?

Dr. Stefanie Demirci reasserted on the fact that future trends tend to develop more procedure-specific systems instead of generalistic systems.

Dr. Pablo Lamata wondered if surgical process modelling could determine the best way to perform a procedure although by now, as **Prof. Pierre Jannin** said, it is used to determine the most usual way of accomplishing it.

Prof. Manuel Doblaré raised the question of managing a huge amount of information to determine good surgical process models.

17 June 2011

Session 3: "Assessment"
Chairman: Dr. Werner Korb.

The session started with a talk entitled "Assessment and training for image-guided therapies" by the chairman, **Dr. Werner Korb**. He focused on human errors regarding the use of navigation systems in surgery and how the interaction human-machine is. He presented different assessment approaches and then moved to the necessary actors for assessment: test OR, patient simulators and a framework for assessment. He exposed an example of this setup. Next point of the talk was the description of mode awareness and study of it. He also exposed the importance of a scenario-based training. Next speaker was **Dr. Magdalena Chmarra** with the talk "Optical tracking for surgical skills assessment". She presented the tracking system TrEndo that is based on optical sensors and its application for objective classification of surgeons. Metrics considered in the exploratory analysis are time, path length, depth perception, motion smoothness, angular area and volume. She ended the talk with the results of the classification. Next talk was given by **Dr. Adinda Freudenthal** and was entitled "Human factors and ergonomic process management to increase surgical quality". She shared her experience in two projects she has worked in: ARIS*ER and The interventional cockpit. She presented an interactive model in cycles that related clinical monitoring, technological research and development and investigation of human factors and ergonomic process management. She finished her talk with two examples of cognitive processing research as the starting point for designing image guidance. **Mr. J. Blas Pagador** gave the following talk which was entitled "Augmented Reality Haptic for assessment laparoscopic therapies". He started with an overview of augmented reality devices for training. He exposed that up to now, augmented reality is mainly oriented to sound and graphics but in the future, tactile feedback has to be also enhanced. For that purpose, a tool tracking is necessary as first step before analysis and enhancement. He presented the Augmented Reality Haptic (ARH), its applications and results of accuracy and validity. Last talk was entitled "Approaches for validation and assessment of surgical simulation devices" by **Ms. Luisa F. Sánchez-Peralta**. She started with a review of training devices that are used at Jesús Usón Minimally Invasive Surgery Centre. She explained reliability studies over the presented training devices. She moved then to validity studies: face and content validity as the subjective ones and construct, concurrent and predictive validity as the objective ones. Finally, she presented a validation methodology specifically designed for e-MIS: E-Learning adaptive platforms based on surgical videos for cognitive training of MIS.

After these talks, discussion of session 3 was introduced by Dr. Werner Korb. The following topics were the main ones exposed during the discussion:

Mr. J. Blas Pagador raised the question about how tactile feedback could be enhanced.

Ms. Luisa F. Sánchez-Peralta explained that to measure skills both in training and OR, it would be interesting to use the same measure device in both environments so measured metrics would be the same and therefore it would be easy to compare them.

Dr. Pablo Lamata suggested the use of video analysis as transparent source of information common to all environments.

Prof. Enrique Gómez-Barrena exposed the critical need of comparing training with real procedures and raised the awareness about timing consideration in a real procedure.

Prof. Pierre Jannin suggested that using surgical process modelling the issue of timing in relation to experience can be assessed. He stated that real expertise cover different aspects not only time to accomplish the procedure, but it is also important to make the best decision when facing a crucial situation.

Dr. Werner Korb stated that there are three types of metrics: process, dexterity and cognitive metrics. He wondered how decisions can be assessed and how we could measure and enhance tactile feedback since this issue is not good enough up to now.

Dr. Adinda Freudenthal exposed that team dynamics is a growing area within surgical training.

Dr. Sánchez-Margallo commented that one of the research lines of the Jesús Usón Minimally Invasive Surgery Centre is the measurement of skills before and after training in surgical courses, using different training devices.

Dr. Werner Korb stated that one important issue is to know whether metrics used in studies reflect correctly the reality of the operation room.

Session 4: “Discussion and Report”

Chairmen: Dr. Francisco M. Sánchez-Margallo and Prof. Enrique J. Gómez-Aguilera.

This last session was reduced due to time constraints. Chairmen of the sessions made a review of all mentioned topics along all the discussions of the workshop:

- * Surgical Process Modelling
- * Preoperative data and imaging (image processing, 3D models)
- * Intraoperative data and imaging
- * Registration (non rigid methods, etc)
- * Tracking technologies and methods
- * Biomechanical models (deformation of organs in real time)
- * Visualization
- * Surgical training
- * Assessment of surgical skills
- * Validation and assessment of surgical devices for training

Participants were asked to provide their contributions on future topics and actions after the workshop. Those comments are included in the following point of the scientific report. Finally, Dr. Enrique Gómez-Barrena closed the workshop with a conclusion from the ESF point of view.

3. Assessment of the results, contribution to the future direction of the field, outcome

Image-guided therapy (IGT) interventions are computer-aided surgical techniques that provide additional intraoperative information to physicians. In order to improve surgical practice and patient safety, surgical navigators offer surgeons precise visualization and guidance within the surgical site. Furthermore, IGT systems are being essential for new surgical concepts development and techniques addressed within this research area a crucial need to reduce medical costs, improve clinical outcome and patient safety.

The goal of the workshop has been to bring together EU scientists, clinicians and biomedical engineering experts working on interdisciplinary and complementary disciplines, all of them focused on IGT for minimally invasive surgery. During the workshop, methods and

technologies involved in the development of new navigation systems were presented and discussed such as soft-tissue surgical procedures, cognitive ergonomics, endoscopic video analysis, intraoperative imaging acquisition, image registration, real-time tracking and deformation of the virtual models of organs.

The participants' presentations, discussion and reports of the different panels have been very fruitful and allowed to define a research framework for IGS in Europe including future directions and main topics to be addressed in this area. These recommendations will serve as an input for new EU research programmes needs such as the next Framework Program, (recently announced its name: Horizon 2020) and other ESF action lines.

The main research topics pointed out at the workshop to be addressed in future actions involve:

- *Multidisciplinary research team in the OR*: Engineers have to participate in the OR to observe the real clinical problems they aim to solve. Likewise, workshops between clinicians and technologists are valuable for presenting scenarios and brainstorming solutions to go for.
- *Evaluate the value of technology during training and clinical situations (e.g., VR, AR, physical/synthetic electronic models, etc.) and methods of evaluation*: evaluations of young surgeons just after they receive training in different scenarios. and how this evaluation must be done.
- *Validation of new technology*: surgeons need to be confident with the developed technology. A comparison of procedures assisted with navigation systems and without them should be made.
- *Development of Test- and Training-Ours*: simulation of environment and surgical equipment, development of measurement tools...
- *Navigation requirements*: Human factors, safety, medical performance, etc. should be analyzed and validated. New surgical scenarios should be defined. New imaging modalities (i.e. 3D cameras).
- *Surgical Process Modelling*: A representation and analysis of surgical tasks, activities, and phases, both patient-specific and generic, should be made.
- *Preoperative data and imaging*: This issue will lead with the development of new image acquisition methods, decreasing ionizing, cost and timing of preoperative images studies. Development of technological innovations to improve surgical performance.
- *Intraoperative data and imaging*: New intraoperative information will be exploited for providing surgeons with extra information (e.g. endoscopic videos, 3D cameras). Real time analysis of intraoperative data and imaging (compensating physiology complications such as cardiac motion breathing) should be developed and validated.
- *Image registration*: Intraoperative non-linear registration methods should be investigated. Surgeons should be being able to switch on preoperative segmented structures on top of the live video feed during laparoscopic surgery. It would be interesting to bring this into active use during procedures to assess the true clinical value. A priority would be automatic or semiautomatic vessel based registration of preoperative data (CT/MRI) to intraoperative laparoscopic ultrasound.
- *Tracking technologies and methods*: Extensive tracking algorithms have been developed. Tracking goal will lead with the challenge of using non intrusive

methods in the OR. Endoscopic video processing will play a critical role to this aim. Combine tracking with image processing to achieve real time.

- *Biomechanical models*: Future surgical navigation systems will include the patient specific geometrical and biomechanical models of the anatomy to estimate the position of hidden tumours and critical structures during an intervention. New algorithms will be investigated for the definition of boundary conditions and for the acceleration of biomechanical models for realtime application.
- *Visualization and interaction*: This challenge should deal with the problem of introducing new equipment safely in the OR. Ergonomic studies will be performed, analyzing sensory, cognitive, physical and organizational issues. Moreover, new tools (e.g. laparoscopic virtual mirror) and new interaction paradigms (through Kinect/Wii controls).
- *New navigation schemes within the surgical workflow*: introduction of calibration and usage protocols in the OR.
- *Validation*: Validation of tools, equipment, models, registration, techniques... used in the OR should be addressed as well as training devices. User Interfaces (e.g. non disruptive, supportive, etc.) are too often neglected, making many new Technologies worthless
- *Assessment*: Standards for assessing surgical skills (what, where, how and when should it be assessed? which tasks?), decision systems that integrate relevant information on surgical skills into a single pass/fail decision (e.g. based on machine learning and pattern classification methods
- *Training*: Application of Surgical Process Modelling to the training and assessment of surgical skills in the OR; Development of new tracking solutions for instrument's motion and forces. The use of endoscopic video as a non intrusive tracking source; Design and development of new safe and reproducible training programs exploiting the use of endoscopic video; Research and validation of new assessment metrics for evaluation of surgical performance. Clear definition of 'expert surgeon' (not 'experienced surgeon'), factors that influence performance in MIS, scheduled training plan (what, where, how and when should it be trained?).
- *Ergonomic Studies*: sensory-, cognitive-, physical-, organizational- on all of the above.

Focusing on this topics list and analysis of future actions, it is the intention of the ESF participants under the leadership of the convenors research centers to submit a proposal for a ESF Research Networking Programme focused on Image-Guided Therapies for Minimally Invasive Surgery. Moreover, researchers want to suggest key research topics to be funded under the 8th Framework Programme and also submit a project proposal to Horizon2020. Besides the well-known funding provided by the European Commission researches will apply to the COST Actions.

Another important outcome of the workshop has been the close research relationships established among participants that will generate common efforts for increase the scientific productivity of this research field of IGT in Europe.

4. Final programme

Wednesday 15 June 2011

Evening

Arrival and dinner at Jesús Usón Minimally Invasive Surgery Centre

Thursday 16 June 2011

- 09.00-09.05 **Welcome by Convenor**
Francisco Miguel Sánchez Margallo (Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain)
- 09.05-09.20 **Presentation of the European Science Foundation (ESF)**
Enrique Gómez Barrena (ESF Standing Committee for the European Medical Research Councils (EMRC))
- 09.20-11.15 Session 1: Introduction and MIS Needs (Chairman: Francisco M. Sánchez-Margallo and Enrique J. Gómez-Aguilera)**
- 09.20-09.30 **Presentation 1 "New approaches of laparoscopic therapies"**
Francisco Miguel Sánchez Margallo (Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain)
- 09.30-09.40 **Presentation 2 "The importance of intraoperative imaging and navigation technologies in MIS"**
Thomas Langø (SINTEF, Trondheim, Norway)
- 09.40-09.50 **Presentation 3 "Image-Guided Technologies for Minimally Invasive Surgery"**
Enrique J Gómez (Bioengineering and Telemedicine Centre, Technical University of Madrid, Madrid, Spain)
- 09.50-10.40 **Discussion**
- 10.40-11.15 *Coffee break*
- 11.15-13.00 Session 2: Image-Guided Interventions Part I (Chairman: Stijn de Buck)**
- 11.15-11.25 **Presentation 4 "Intra-operative image acquisition"**
Stijn de Buck (Medical Imaging Center, Katholieke Universiteit Leuven, Leuven, Belgium)
- 11.25-11.35 **Presentation 5 "Considerations on 3D Models for interactive surgery"**
João Oliveira (International Centre for Technologies in Virtual Reality, Portalegre, Portugal)
- 11.35-11.45 **Presentation 6 "3D image processing for image-guided therapies"**
Kawal Rhode (King's College London, London, UK)
- 11.45-11.55 **Presentation 7 "Intra-operative surface reconstruction for Augmented Reality (AR) guidance in computer-assisted laparoscopic interventions"**
Lena Maier-Hein (German Cancer Research Center, Division of Medical and Biological Informatics, Heidelberg, Germany)
- 11.55-12.05 **Presentation 8 "Intra-operative Navigation: Calibration and Visualization"**
Stefanie Demirci (Technische Universität München, Munich, Germany)
- 12.05-12.15 **Presentation 9 "The Resection Map as guidance during liver interventions"**
Pablo Lamata (University of Oxford, Oxford, UK)
- 12.15-12.25 **Presentation 10 "Model based liver segmentation for surgery planning"**
Martijn Hemeryck (Medical Imaging Center, Katholieke Universiteit Leuven, Leuven, Belgium)
- 12.25-13.00 *Discussion*

- 13.00-14.30 *Lunch*
- 14.30-17.00** **Session 2: Image-Guided Interventions Part II (Chairman: Pierre Jannin)**
- 14.30-14.40 **Presentation 11 "Laparoscopic video analysis as an intraoperative source of information"**
Patricia Sánchez (Bioengineering and Telemedicine Centre, Technical University of Madrid, Madrid, Spain)
- 14.40-14.50 **Presentation 12 "MITK platform for developing new navigation systems"**
Matthias Baumhauer (German Cancer Research Center, Division of Medical and Biological Informatics, Heidelberg, Germany)
- 14.50-15.00 **Presentation 13 "Real-time detection and tracking for augmented reality environments"**
Judith Mühl (Institute for graphics and computer vision, Graz, Austria)
- 15.00-15.10 **Presentation 14 "Biomechanical models of soft tissues: real-time applications"**
Estefanía Peña (University of Zaragoza, Zaragoza, Spain)
- 15.10-15.20 **Presentation 15 "Intraoperative tracking for laparoscopic surgery"**
Sandrine Voros (Laboratoire TIMC-IMAG, La Tronche Cedex, France)
- 15.20-15.50 *Coffee / tea break*
- 15.50-16.00 **Presentation 16 "3D reconstruction of the surgical scene using structured light"**
Marcos A. Rodrigues (Sheffield Hallam University, Sheffield, UK)
- 16.00-16.10 **Presentation 17 "The role of industry in the progress of image-guided procedures"**
John Hyde (Perception, Sensors and Instrumentation, Doncaster, UK)
- 16.10-16.20 **Presentation 18 "Surgical Process Modelling"**
Pierre Jannin (INSERM / INRIA / IRISA, Rennes cedex, France)
- 16.20-17.00 **Discussion**
- 18.30 *Guided visit*
- 20.30 *Dinner at Parador de Turismo de Cáceres*

Friday 17 June 2011

- 09.00-11.00** **Session 3: Assessment (Chairman: Werner Korb)**
- 09.00-09.10 **Presentation 19 "Assessment and training for image-guided therapies"**
Werner Korb (Innovative Surgical Training Technologies, Leipzig, Germany)
- 09.10-09.20 **Presentation 20 "Optical tracking for surgical skills assessment"**
Magdalena Chmarra (Technical University Delft, Delft, The Netherlands)
- 09.20-09.30 **Presentation 21 "Human factors and ergonomic process management to increase surgical quality"**
Adinda Freudenthal (Technical University Delft, Delft, The Netherlands)
- 09.30-09.40 **Presentation 22 "Augmented Reality Haptic for assessment laparoscopic therapies"**
J. Blas Pagador (Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain)
- 09.40-9.50 **Presentation 23 "Approaches for validation and assessment of surgical simulation devices"**
Luisa F. Sánchez-Peralta (Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain)
- 9.50-10.30 **Discussion**

10.30-11.15	<i>Visit to JUMISC facilities</i>
11.15-11.45	<i>Coffee</i>
11.45-12.30	Session 4: Discussion and Report (Chairmen: Francisco M Sánchez-Margallo and Enrique J. Gómez Aguilera)
11.45-12.30	follow-up research activities, future collaborative actions...
12.30	<i>End of Workshop and departure</i>

5. Final list of participants

Participants are listed in name alphabetical order, followed by the institution they belong to, the city and the country.

Convenor:

Francisco M. Sánchez Margallo - Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain

Co-convenor:

Enrique J. Gómez -Bioengineering and Telemedicine Centre, Technical University of Madrid, Madrid, Spain

Participants:

Adinda Freudenthal - Technical University Delft, Delft, The Netherlands

Estefanía Peña - University of Zaragoza, Zaragoza, Spain

J. Blas Pagador - Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain

João Oliveira - International Centre for Technologies in Virtual Reality, Portalegre, Portugal

John Hyde - Perception, Sensors and Instrumentation, Doncaster, UK

Judith Mühl - Institute for graphics and computer vision, Graz, Austria

Kawal Rhode - King's College London, London, UK

Lena Maier-Hein - German Cancer Research Center, Division of Medical and Biological Informatics, Heidelberg, Germany

Luisa F. Sánchez-Peralta - Jesús Usón Minimally Invasive Surgery Centre, Cáceres, Spain

Magdalena Chmarra - Technical University Delft, Delft, The Netherlands

Manuel Doblaré - University of Zaragoza, Zaragoza, Spain

Marcos A. Rodrigues - Sheffiled Hallam University, Sheffield, UK

Martijn Hemeryck - Medical Imaging Center, Katholieke Universiteit Leuven, Leuven, Belgium

Matthias Baumhauer - German Cancer Research Center, Division of Medical and Biological Informatics, Heidelberg, Germany

Pablo Lamata - University of Oxford, Oxford, UK

Patricia Sánchez - Bioengineering and Telemedicine Centre, Technical University of Madrid, Madrid, Spain

Pierre Jannin - INSERM / INRIA / IRISA, Rennes cedex, France

Sandrine Voros - Laboratoire TIMC-IMAG, La Tronche Cedex, France

Stefanie Demirci - Technische Universität München, Munich, Germany

Stijn de Buck - Medical Imaging Center, Katholieke Universiteit Leuven, Leuven, Belgium

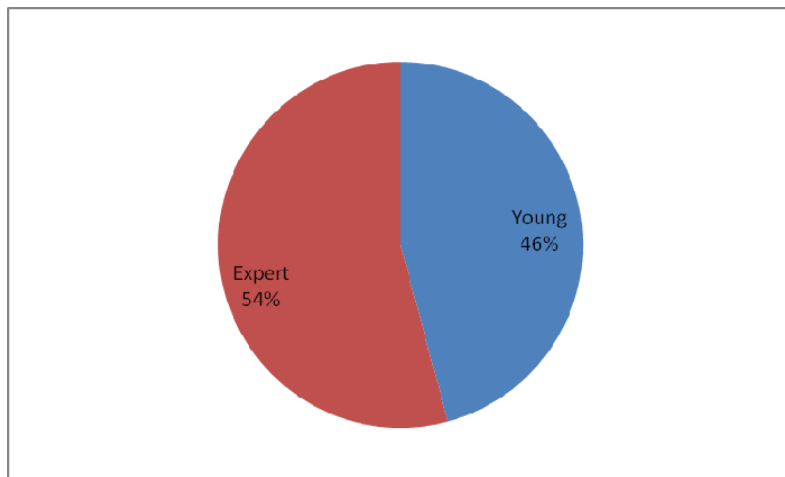
Thomas Langø - SINTEF, Trondheim, Norway

Werner Korb - Innovative Surgical Training Technologies, Leipzig, Germany

6. Statistical information on participants

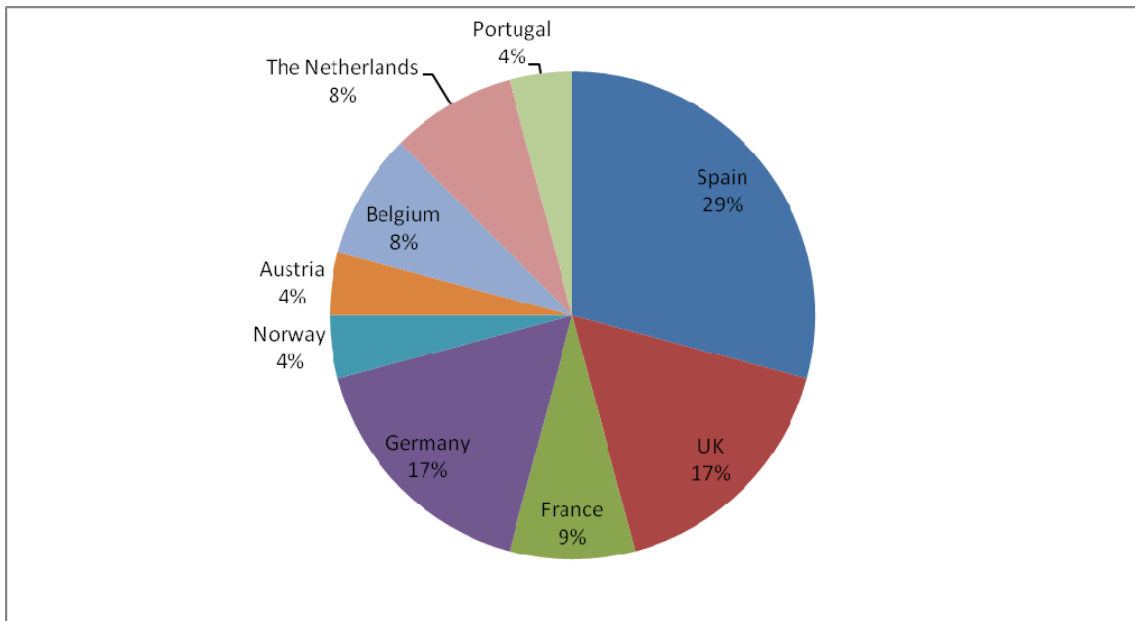
* Expertise

Range	Number of participants
Young scientist	11
Expert scientist	13



Geographical distribution

Country	Number of participants
Austria	1
Belgium	2
France	2
Germany	4
Norway	1
Portugal	1
Spain	7
The Netherlands	2
United Kingdom	4



* Gender distribution

Gender	Number of participants
Female	9
Male	15

